MRI Analysis of Brain Volume Changes in Dementia

1. Introduction

Dementia can cause significant impairments in cognition and activities of daily living life that often show in structural brain changes seen in Magnetic Resonance Imaging (MRI). The purpose of this study is to analyze MRI data and capture how changes show through changes in normalized whole brain volume (nWBV) and Atlas Scaling Factor (ASF) which indicate brain atrophy due to dementia.

The data named 'INF2178_A4_data.csv' from a longitudinal study on MRI results of patients with/without dementia will be used to explore within-subject design and statistical power. Utilizing mixed-effects Analysis of Variance, the research examines the dynamic relationship between dementia status and brain volume changes over time, our exploration will address two fundamental research questions:

1. How does the Normalized Whole Brain Volume (nWBV) vary across different visits for each group (Demented, Nondemented and converted), and is there an interaction effect between visits and group status on nWBV changes?
2. How does the Atlas Scaling Factor (ASF) vary across different visits for each group (Demented, Nondemented and converted), and is there an interaction effect between visits and group status on ASF changes?

2. Data Cleaning

The raw data set has 294 rows and 16 columns, and we have reduced our working data to 5 columns.

Subject ID: identifier of the study subject.
Group: The study group dementia status(demented, nondemented and converted)
Visit: The number of visit times.
nWBV: Normalized Whole Brain Volume, a measure related to brain size.
ASF: Atlas Scaling Factor, used in brain volume measurements.

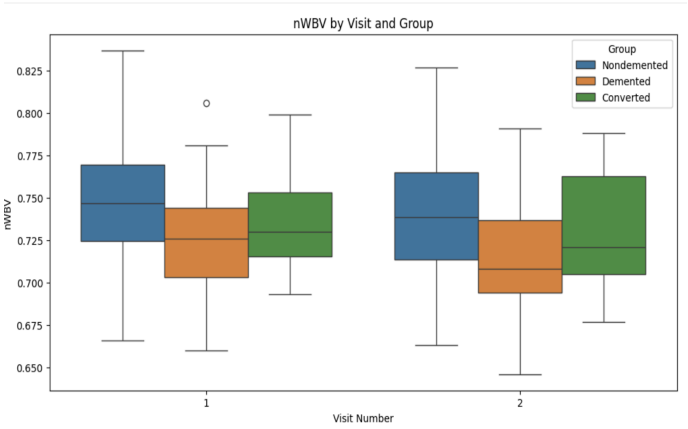
Now we have 294 rows and 5 columns, after checking, there are no missing values in this data.

3. EDA

index	Visit	nWBV	ASF
count	294.0	294.0	294.0
mean	1.489796	0.731381	1.203109
std	0.500748	0.037373	0.139365
min	1.0	0.646	0.876
25%	1.0	0.703	1.118250
50%	1.0	0.732	1.201
75%	2.0	0.756	1.30275
max	2.0	0.837	1.587

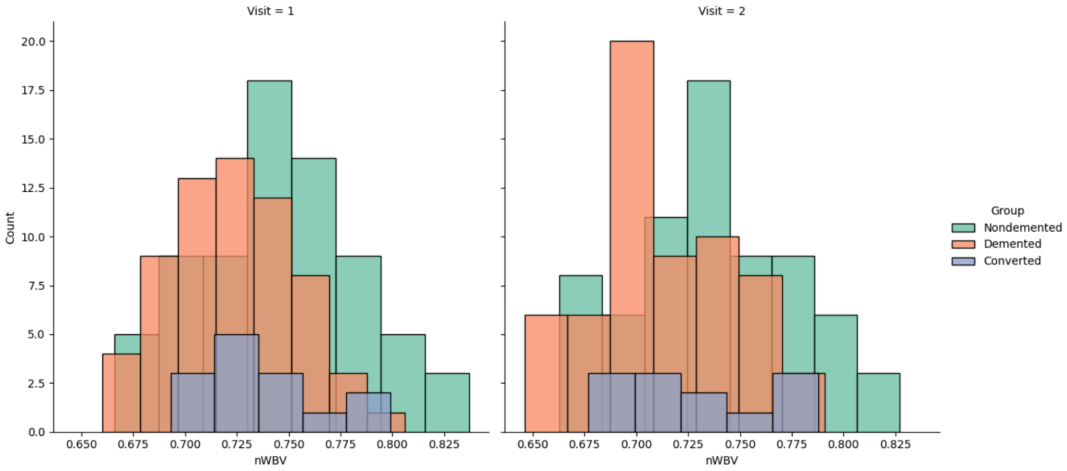
First, we have created a summary table to check the statistics of the Visit, nWBV, ASF columns in this dataset.(showing above)

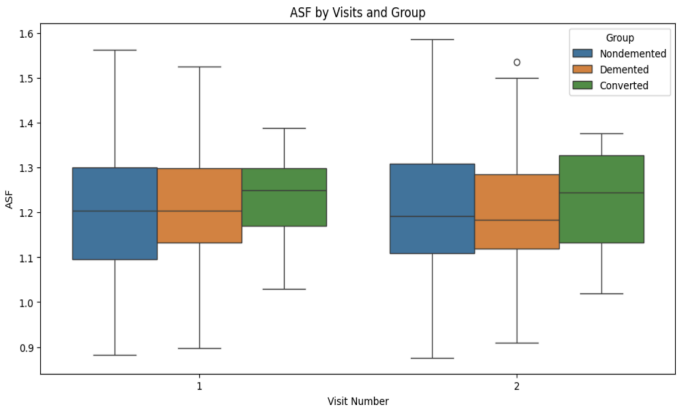
Now we use the boxplot to visualize the distribution of normalized whole brain volume (nWBV) across visits for three patient groups: Nondemented, Demented, and Converted:



In the boxplot, the median of normalized whole brain volume shows highest for the Nondemented group during the first visit, with a slight reduction by the second visit. The Demented group shows consistently lower median nWBV values across both visits when compared to the other groups. The Converted group, representing individuals who transfer from Nondemented to Demented, also shows a slight decrease by the second visit in the median of nWBV.

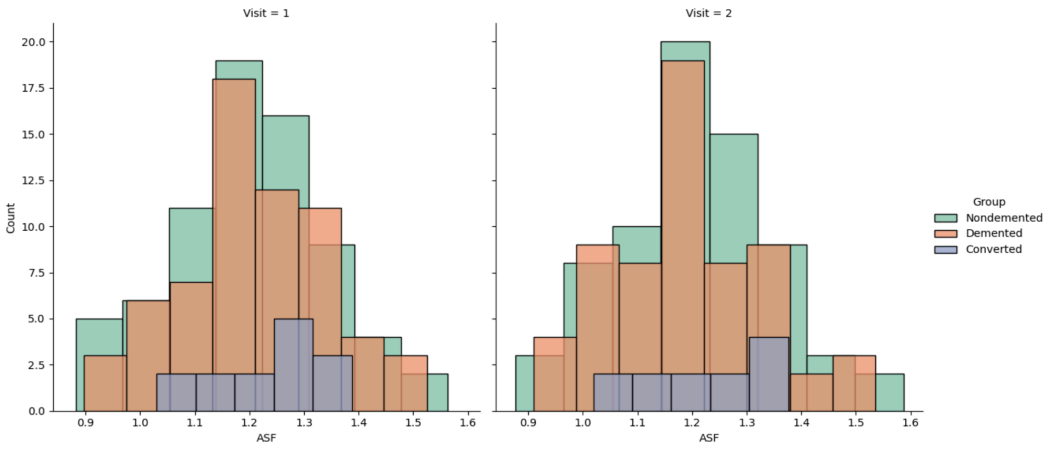
We also create histogram represents the distribution of normalized whole brain volume (nWBV) across visits for three patient groups: Nondemented, Demented, and Converted:





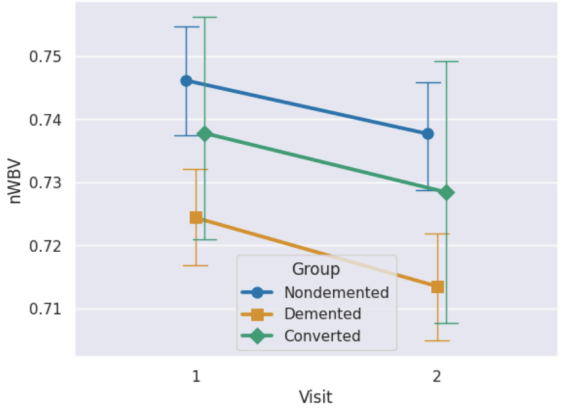
This boxplot shows the distribution of Atlas Scaling Factor (ASF) across visits for three groups: Nondemented, demented and converted. All of the three group types indicate a slight decreasing trend on the median of Atlas Scaling Factor from visit 1 to visit 2.

The histogram distribution of Atlas Scaling Factor (ASF) across visits for three patient groups is shown below:



4. Mixed Effects ANOVA Analysis

For the first research questions: How does the Normalized Whole Brain Volume (nWBV) vary across different visits for each group (Demented, Nondemented and converted), and is there an interaction effect between visits and group status on nWBV changes?



The output plot illustrates the change of normalized whole brain volume (nWBV) across different visits for three patient groups, nWBV is decreasing in all groups. For the demented group, there's a notable decrease in nWBV. Plot also suggests a significant reduction in nWBV on the converted group from visit 1 to 2.

Now I perform the mixed effect ANOVA result table:

Source	SS	DF1	DF2	MS	F	p-unc	np2
Group	0.0336	2	141	0.0168	6.712	0.002	0.087
Visit	0.0065	1	141	0.0065	94.251	2.227e-17	0.401
Interaction	0.0002	2	141	0.0001	1.534	0.219	0.021

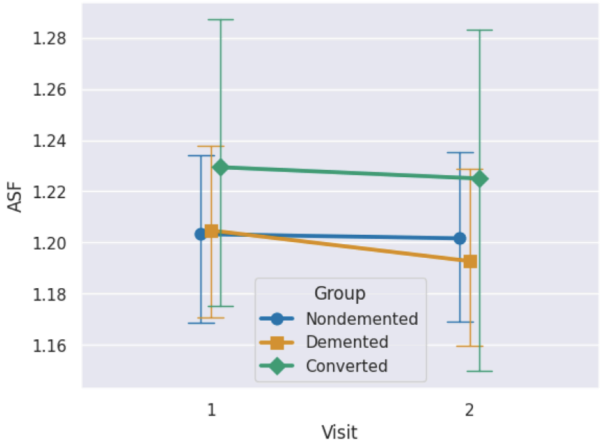
This table presents the results of a mixed-effect ANOVA, it reveals that there is a significant difference in normalized whole brain volume (nWBV) both between the groups(p value = 0.002) and across visit times(p value <0.001), large positive F statistics also supports these findings. However, the large p value(0.219) and F(1.534) suggests a lack of significant interaction effect on nWBV, implying that the difference of nWBV does not significantly vary across visits for groups.

Assumption check: Assumption 1: mauchly's test of spericity: the result of this test shows p value = 1 > 0.05, assumption met.

Assumption 2: Normality is met, since the p value > 0.05 and the true normal status.

Assumption 3: Homogeneity of variance is also met, supported by the p value > 0.05.

Second research question: How does the Atlas Scaling Factor (ASF) vary across different visits for each group (Demented, Nondemented and converted), and is there an interaction effect between visits and group status on ASF changes?

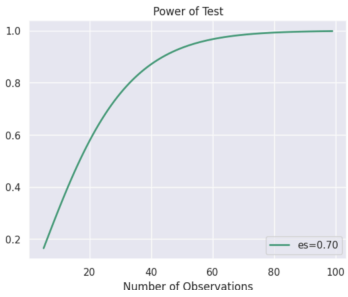


This output plot displays the Atlas Scaling Factor (ASF) across different visits for three patient groups, it shows that both the Nondemented and converted group has a slight decrease in ASF from Visit 1 to Visit 2, however, demented group has the more significant reduction in ASF across different visits.

Source	SS	DF1	DF2	MS	F	p-unc	np2
Group	0.0184	2	141	0.0092	0.234	0.792	0.003
Visit	0.0032	1	141	0.0032	8.754	0.004	0.058
Interaction	0.0007	2	141	0.0004	1.028	0.361	0.014

This table presents the results of a mixed-effect ANOVA, it reveals that Atlas Scaling Factor (ASF) varies significantly across different visits(p value = 0.004) but there is no significant difference in ASF between the patient groups. Furthermore, a lack of significant interaction(between group and visit) effect on ASF is proved by the p value which is 0.361.
Assumptions : mauchly's test of spericity: the result of this test shows p value = 1 > 0.05, assumption met. Normality is met, since the p value > 0.05 and the true normal status. Homogeneity of variance is also met, supported by the p value > 0.05.

5. Power plot for t-test:



Given the power 0.91, effect size 0.7, alpha level(0.05) in the analysis, we have found that the appropriate sample size in each group should be 45.451, which is 46 rounded up to an integer. This power plot also indicates a positive relation between sample size and the power of the test.

6. Conclusion: Overall Normalized Whole Brain Volume(nWBV) varies significantly between groups and also across visits, but there isn't a significant interaction effect from groups and visits on nWBV. Atlas Scaling Factor (ASF) changes significantly across different visits, but not between the patient groups. Also, the interaction effect on ASF is not significant.